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PREDICTION OF THE THICK FILM RESISTOR TRIMMING

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Anotace:
Tento výzkum se zabývá tlustovrstvovou technologií. Především je tato práce zaměřena na dostavování hodnoty odporu tlustovrstvového rezistoru. Hlavním zájmem bylo použití simulačního program pro predikci hodnoty výsledného rezistoru. Laserové dostavování se používá k přesnému dostavení tlustovrstvých rezistorů a tato oblast je vhodná pro použití simulačních programů. Další oblast zájmu byla z pohledu výkonového zatížení jednotlivých řezů a možnosti jejich měření. V tomto článku bylo vybráno šest řezů k porovnání výkonového zatížení a korelaci se simulačním programem. Jako simulační nástroj byl vybrán ANSYS Workbench.

This research deals with the issue of the thick-film technology. This work is focused especially on the trimming value of resistance thick-film resistors. The main aim is to use simulation program for resistance value prediction. The laser trimming is used to ensure accurate values of thick film resistors. Another area of interest is the power load of individual cuts and the possibilities of measuring them. In this paper, six cuts were selected to compare power load and correlation with simulations from the Ansys Workbench program was done.

INTRODUCTION

Thick film technology has been in use for decades and it still offers us a place to research. This technology uses special pastes that have the electrical properties of the circuit: resistive, capacitive, inductive and special.

Different deposition methods are used to make this motives. The first way is the screen printing. Stencil printing is the second type of deposition. The last one is dispensing printing. In this case, a screen printing was used to create motives. Although this technology offers many excellent features, the greatest disadvantage is the accuracy of the printed resistor. The printed resistor usually require trimming. In the past, sandblasting was used. This technology has achieved appropriate results, but this technology is unclean and needs to be replaced. [1],[2]

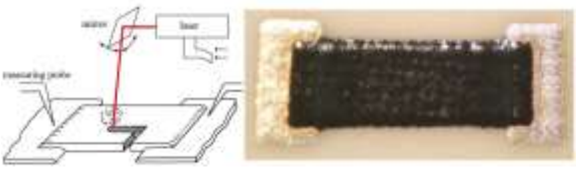

Fig. 1: Laser trimming / thick film resistor

For this reason, the laser beam (Fig. 1) is used to trim the resistor today. The resistance is trimmed by a focused beam of light directed against the resistive material. Because the lasers are pulsed, the resistive material is removed in parts. During the evaporation of the resistive material, the resistance is measured with the probes simultaneously. Two types of lasers are used most frequently: CO2 laser or YAG: Nd laser. The advantage of YAG:Nd laser is a small wavelength, thus there is a low absorption of the beam on the ceramic substrate.

Therefore, the resistance paste evaporates primarily. The CO2 laser has a high pulse wavelength, which can lead not only to the evaporation of the resistance paste but also to the substrate surface disruption, so the CO2 laser is used to cut the ceramic substrates not for trimming. Another advantage of YAG:Nd laser is the diameter of the laser beam trace, which can reach values up to 10 μm. The CO2 laser has a beam diameter of 10x greater (100 μm) than the YAG: Nd laser. For the above reasons, YAG: Nd laser is more often used for trimming. In our case, we used YAG:Nd Aurel laser type ALS300 with 5 W continuous mode and 25 W pulse mode. This device is controlled by a PROTOMAT software. The diameter of the laser beam is 40 - 60 μm.[3],[4]

TYPES OF CUTS

Strain cut

Strain cut (Fig. 2) is the easiest and the fastest way to resize the resistor. It is simple and fast to execute. It is economically the most advantageous cut but at the cost of less accurate trimming. The maximum accuracy of this type is within ± 0.50%. Minor delivery accuracy is due to the exponential growth of resistance with the length of the cut.

L-cut

L-cut (Fig. 2) is based on strain cut but the problem of exponential growth of resistance is solved here. This cut is one of the most common cuts. Due to the cutting speed and accuracy of the resistor up to ± 0.30%. The disadvantage of this cut is short-term stability.

L-cut with Vernier cut

This type of cut is used to get the L-cut (Fig. 2) more accurately and at the same time, it achieves greater long-term stability than the L-cut and D-cut. The disadvantage of this cut is the longer time of the trimming.

Double cut

Another cut (Fig. 2) that compensates the exponential growth of resistance with the length of the cut is a double cut. The double cut is based on the strain cut where a second shorter cut is added next to the first cut. An accuracy of ± 0,20 % is achieved in this section. The double cut is suitable for short resistors where the use of L-cut is not as effective. The advantage of a double cut is greater long-term stability than the L-cut.

Double Reserve cut

A double reversed cut (Fig. 2) is used if we need to make a large change in resistance and we do not have a sufficiently long resistor to use the serpentine cut. The disadvantage of this cut is the low accuracy of the resistor's nominal value and short-term stability.

U-cut

The U-cut (Fig. 2) is similar to the L-cut, practically the finished L-cut, which makes the whole bottom part electrically insulated. For this reason, this type of cut is suitable for high-voltage applications. The disadvantage of this cut is the accuracy, which is within ± 1.0% of the nominal value.

Fig. 2: Strain cut, L-cut, Vernier cut, Double cut, Double reverse cut, U-cut

EXPERIMENTS

The resistor (Fig. 3) has been designed to be trimmed with 3 kΩ final value. For statistical purposes, the substrate was designed to create eleven samples from each cut. The substrate contained eight rows of eleven columns for trimming and the possibility to test up to eight different types of cuts. The Tesla Lanskroun TT5031 paste was used for the resistance layer. The resulting dimensions of the resistor can be seen in figure 3. A substrate of 50.8 x 50.8 mm and a thickness of 0.63 mm was used for testing.

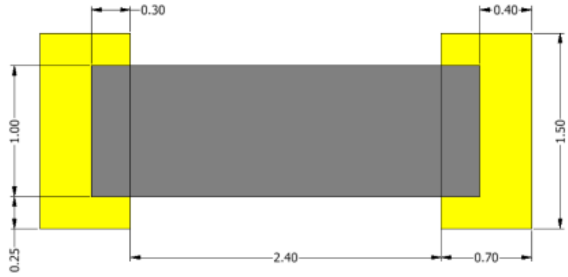

Fig. 3: Dimension of the thick film resistor

Various types of cuts are used to trimming the resistance due to the change in the electrical properties of the resistor. By cutting into the resistor structure, the properties of the resistor are changed dramatically. For example, the current flow through the resistor is very inhomogeneous. This influences the resistor power load, long-term stability, TCR and other parameters that are important for the use of a resistor in the electric circuit. For the correctness of the results, eleven of each cut listed above were performed. Table 1 shows the value before trimming, the value after trimming, the lowest difference from the nominal value of 3kΩ and the average value of this difference of all eleven cuts.

Tab. 1: Table of cuts

Type	*R1 [kΩ]*	*R2 [kΩ]*	*Lowest diff[%]*	*Avg diff[%]*
Strain cut	2,584	3,027	0,92	1,46
L-cut	2,094	3,013	0,43	0,55
Vernier	2,086	3,005	0,15	0,20
Double cut	2,189	3,013	0,43	0,61
Reverse	2,649	3,022	0,72	0,82
U-cut	2,473	3,005	0,17	0,32

SIMULATION

For the simulation and setting of initial conditions and material properties, it was necessary to calculate the resistivity of the thick film. The simulation program needs to set the material using resistivity (Ω.m). Therefore, the height of the layer was measured, and resistivity calculated for all the cuts used. From these results, the average was 1,8584·10-2 $\Omega{\cdot}m$ and this was used for the simulation. Six of cuts were simulated. The resulting simulation display the current density in the thick film resistor. The simulation shows place with the highest load. Another parameter was to find out how to predict the length of the cut. For clarity, Vernier was chosen to be the most accurate.

A cut of 290 µm was required to trim the resistor of the first section of the L-cut (Fig. 4). Trimming stop at 30% of the final value. According to theoretical assumptions, it was known that a 1% to 2% of the nominal value could be trimmed by the last cut. A second part of the L-cut 810 μm was needed to get 2,97460 kΩ. The cut was placed 200 μm before the L-cut, ie 400 μm from the conductive pad. To reach the resistor at a value close to the higher nominal value of 3 kΩ, the length of the slicing section must be 210 μm long. Then the resistor resistance will be 3,00291 kΩ according to the simulation program. The accuracy of the resistor is 0.10% from the nominal value.

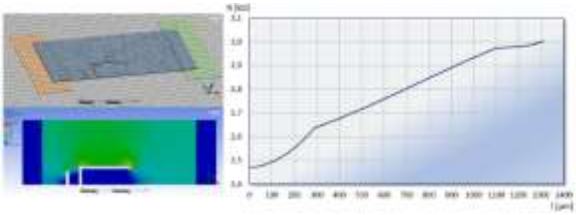

Fig. 4: Mesh of the model, Current density simulation, Resistivity depends on the length of cut

The last part of the research is focused on the measurement with the thermal camera to determine the actual heat distribution. From this, it is possible to see the thermal load of certain cuts. Vernier cut was selected for clarity. The problem with this measurement was that the long side of the resistor was only 2.4 mm. From this point of view, it is very difficult to measure thermovision camera and it is necessary to use a special lens. The figure 5 shows the actual temperature distribution. The temperature distribution corresponds to the simulation. The highest thermal load is at the corners of the cut.

Table 2 shows the maximum and minimum temperatures of all cuts. It can be assumed that the smallest thermal load is at the U-cut. When the heat is spread to the whole but not to edge of the cut.

Tab. 2: Temperature distribution

Type	*Tmax[]*	*Tmin[]*
Strain cut	2,584	3,027
L-cut	2,094	3,013
Vernier	2,086	3,005
Double cut	2,189	3,013
Reverse	2,649	3,022
U-cut	2,473	3,005

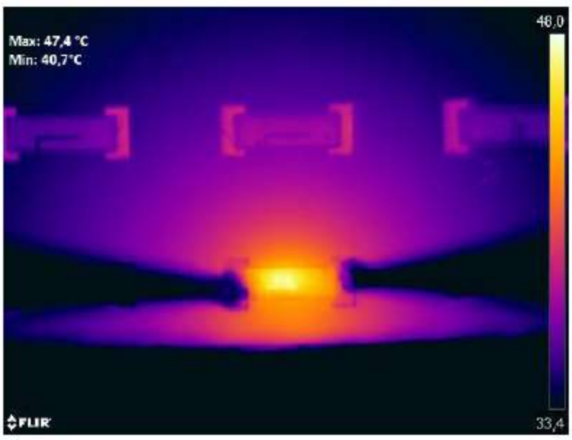

Fig. 5: Thermal distribution

CONCLUSION

This paper deals with the possibility of simulation being used as a prediction tool for trimming resistors. It was possible to create models of resistors that achieved values as real created and values of trim lengths agreed with reals one. The prediction was possible for all six tested cuts. The last part of this research deals with the thermal load of different types of cuts. With the lowest thermal load is U-cut and the highest one with thermal load is strain cut.tuto šablonu.

ACKNOWLEDGMENTS

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